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PRELIMINARY EXAMINATION OF PARTICLES COLLECTED BY THE LUSTER SOUNDING ROCKET EXPERIMENT

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ABSTRACT

A Luster micrometeoroid sampling instrument was carried by an Aerobee 150 sounding rocket to an altitude of 145 km during the November 1965 Leonid meteor shower. Cleaned and preevacuated sealed modules containing sampling surfaces were installed on the instrument prior to launch. The instrument opened, on ascent, at 64 km and closed, on descent, at 116 km, exposing one square meter of sampling surface vertically and another square meter horizontally for 200 seconds. The instrument was parachuted to earth after severance from the rocket. Vacuum sealed modules containing the samples were removed from the instrument and taken to the clean-room laboratory for analysis. An extensive contamination control program was utilized to exclude terrestrial material from the flight instrument and sampling surfaces.

Electron microprobe analyses of particles found by optical microscopy on $1.4 \times 10^{-2} \text{ M}^2$ of flight sampling surfaces indicate that only three may have had an extraterrestrial origin. Predictions based on artificial earth satellite and earlier sounding rocket data indicate that more than 50 extraterrestrial particles should have been observed on

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this area. These predictions have not been substantiated by this preliminary survey. The significance of this cannot be fully realized until the entire exposed area has been examined.

INTRODUCTION

The Leonid meteor shower which recurs annually in November is attributed to the comet Tempel-Tuttle (1866I) whose orbit coincides with that of the meteor stream [Porter, 1963]. The shower has exhibited periods of great intensity every 33 or 34 years since its earliest recorded occurrence in 902 A. D. [Watson, 1962]. An increase in the influx rate of particles in the Leonid shower of 1965 or 1966 was predicted on the basis of this cyclic behavior of the stream. An examination of radar observations [Sky and Telescope, 1963a][McIntosh, 1966] and visual counts [Sky and Telescope, 1962, 1963b, 1964, 1965, 1966] of the Leonids for the past few years confirms this prediction (see Figure 1).

Little is known concerning the composition of Leonid meteor particles, except for that learned from spectra of the ablation observed as the high speed particles enter the earth's atmosphere. Spectra obtained on these meteors [Millman and McKinley, 1963][Rao and Lokanadham, 1963a, 1963b] indicate a stony type of particle having the major elements, Ca, Mg, Fe, Si, O, and Na.

In order to learn more about the physical and chemical characteristics of the dust particles in this meteor stream and about the comet from which they come, a physical collection of the particles was attempted

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using a recoverable sounding rocket. The Luster micrometeoroid sampling instrument was launched (and successfully recovered) November 16, 1965 at 1600 (U. T.) within a few hours of the estimated peak of the shower [Sky and Telescope, 1966].

PREDICTED PARTICLE COLLECTION

The Leonid meteor stream was detected by Berg in 1955 [Berg and Meredith, 1956] using an Aerobee rocket equipped with a device to detect the impact flash of high speed particles striking a detector. The high influx rate he recorded was not confirmed by later rocket flights by Lovering [1959] or by Berg in 1960 [Dubin et al., 1963]. The artificial earth satellite, Vanguard III, detected this meteor stream in November 1959 with a microphone detector. Alexander et al. [1961] reported a major increase in impact rate during the November 15-18 period from this satellite. An approximate influx rate from their data [Alexander et al., 1962] has been used to predict the numbers of particles larger than certain sizes which might be intercepted by the Luster sampling surfaces during their exposure. Table 1 shows this estimate for the Leonid shower peak rate.

TABLE 1.- PREDICTED EXTRATERRESTRIAL PARTICLE COLLECTION

Data source	Number greater than indicated size per square meter for a 200-sec flight		
	1 μ	4 μ	8 μ
Vanguard III satellite, Nov. 1959, Leonid shower peak	no data	4,000	100
Venus Flytrap rocket, June 1961	180,000	24,000	6,000
Satellites, rockets, and visual sightings - annual average	20,000	200	10

Hemenway and Soberman [1962] launched and recovered the Venus Flytrap micrometeoroid collector on June 6, 1961. They detected a high influx rate which they believe may have been due to sampling a daytime meteor shower. Recently, using more sophisticated methods [Soberman and Hemenway, 1965], they have recalculated the flux encountered by this flight. These later data have been used to estimate the approximate number of particles which might be collected by the Luster flight if the Leonid shower is similar. This estimate is shown in Table 1 as the Venus Flytrap collection.

Dubin [1963] has summarized presently known particle-flux values obtained from many sources. This average influx rate has been used to estimate the magnitude of the Luster collection during nonshower periods. It is shown in Table 1 as the annual average for all data accumulated from satellite detectors, rocket collections, and visual sightings. If these various flux data are reasonably related to the visual and radar observations of the Leonid shower maxima (see Figure 1), then the influx rate at the time of the Luster flight in 1965 should have been significantly larger than has been predicted in Table 1 from the Vanguard III data which were obtained in 1959.

EXPERIMENTAL METHOD

The Luster payload consists of the sampling instrument, an electronics package, and a recovery package. The sampling instrument has a sealed enclosure which rises, exposing the arms when the programmed altitude is reached. The three 5-foot arms are hinged at the

base of the instrument and are deployed perpendicular to the axis of the payload with the four module pans on each arm facing upward along the flight path. These pans expose a square meter of area in the vertical direction. The mating covers remain fixed to the central structure and expose another square meter of area horizontally. Prior to reentering the atmosphere the arms are retracted, mating the pans with covers, and the enclosure is closed, resealing the instrument from the outside environment. A prototype sampling instrument is shown during the open cycle in Figure 2. The launch vehicle for this payload was the Aerobee 150 sounding rocket. Time versus altitude data are shown in Figure 3 for the November 1965 Luster flight.

The basic sampling surface used in the flight was a thin methyl methacrylate slide 5.1×5.7 cm. All slides were marked with 2.5-mm ruled squares. This permits orderly scanning of the slides and simplifies subsequent relocation of particles for further analysis.

Some of the basic slides were shadow coated in vacuum with aluminum or copper films to aid the identification of contaminants and enhance the detection of impact craters. Others were overlaid with thin films of polyvinyl chloride (PVC), heavily plasticized to provide tacky surfaces so that the particles retained on these and untreated plastic and metal surfaces could be compared. Highly polished copper squares and quartz plates were also attached to some slides. These plates were to be inserted directly in the electron microprobe where particles on them could be analyzed without separate handling. Also, several reagent films for detecting iron in particles and for indicating

soluble halides [Farlow, 1957] were included. Numerous control slides representing all slide types were sealed in modules which were processed in an identical fashion to flight modules but were not flown. A few control slides which had electron microscope screens attached were flown with half the slide and screens shielded from direct particle impact by plastic cover slips to aid in the comparison of flight collected particles with possible contaminants.

The slides were attached directly to the module pans and covers. Half the area on each module cover was coated with a thin film of PVC. This can be easily stripped from the cover and dissolved and filtered through membrane filters to concentrate particles from a large collection area onto a small area to aid the optical search.

A primary requirement imposed on the Luster experiment was that of cleanliness [Blanchard and Farlow, 1966]. Sampling surfaces were prepared in an environment having no particles larger than 0.5μ per $0.03M^3$ of air (Fed. Std. 209, Class 100). Contamination control was maintained throughout their transportation, flight, recovery, and analysis. To accomplish this, the vacuum sealed module concept was imposed. Module pans and covers were assembled and vacuum sealed in the Ames clean laboratory and installed as sealed units on the instrument in a similar environment prior to flight. They were opened only during sampling and later for analysis. During reentry of the instrument into the atmosphere, the modules were vacuum resealed as the outside atmospheric pressure rose and remained sealed until opened for analysis. Similar contamination controls using class 100 clean rooms were applied

during the assembly, test, and integration of the flight instrument. Thus, the sampling surfaces, modules, and interior of the sampling instrument were never exposed to uncontrolled earth environments during the experiment.

Guest scientists participated extensively in the Luster experiment. Five scientists representing England, France, Israel, Sweden, and West Germany utilized one European module. Seven United States guests utilized three separate modules, and shared part of one Ames module. Thus, 4 of the 12 modules were loaded and vacuum sealed in guest scientists' laboratories and delivered to Ames Research Center sealed in precleaned nylon bags. These modules remained sealed until opened at sampling altitude, then were vacuum resealed on reentry to the atmosphere. They were repackaged in nylon bags upon recovery and returned to guests' laboratories still vacuum sealed. In this manner the results were obtained by each scientist as independently as possible. Results of guest experiments will be published independently of the NASA findings.

RESULTS

Six flight slides ($1.4 \times 10^{-2} \text{M}^2$), representing less than 2 per cent of the total area, and one non-flight control slide have been examined. Both flight and backup slides were optically scanned at a magnification of 120 times. This is sufficient to detect particles as small as 2μ in diameter without difficulty. However, only those 4μ and larger were photomicrographed for this preliminary study. Particles in this size

range which could not be recognized as common contaminants were removed and qualitatively examined in the electron microprobe X-ray analyzer. The thin copper and aluminum coatings on certain plastic slides were searched also for holes of these sizes, which might have been caused by particles impacting at high speed. Three of these slides with a total area of about 70 cm² have been scanned, but none of these holes have been detected.

Thin films of PVC were stripped from the covers of two flight and three non-flight modules. These were separately dissolved and filtered through membrane filters. The filters were scanned optically in the same fashion as the plastic slides. Only unusual particles were chosen from these for study in this initial survey because of the numerous contaminants present.

Particles selected for microprobe analysis were transferred to small quartz squares. Each particle was examined with a finely focused electron beam for elements of atomic number 12 (magnesium) and larger. Only major elements were detected in this qualitative examination. Forty-four particles were examined with the electron microprobe. Of these, 25 were from flight slides, 5 from the PVC films on flight module covers, and the rest from non-flight control surfaces. Only two particles from flight slides and one from a flight module PVC film can be considered as candidates for an extraterrestrial origin. Even in these three cases, considerable skepticism exists concerning an extraterrestrial origin. However, final evaluation awaits more extensive examination of these particles and those from several hundred additional flight slides.

Particle origin is based on several criteria. If a particle contains large amounts of chemical elements which are very rare in cosmic abundance [Cameron, 1959] or in meteorites [Mason, 1962], it is likely to be a contaminant. However, if detailed studies indicate none of these particles occur on the control surfaces, and if no contaminant source can be found in the payload, then an extraterrestrial origin may be suspected. If nearly identical particles having similar physical and chemical characteristics are found on both flight and non-flight slides, then extraterrestrial origin is considered unlikely. If particles on slides which were preshadowed with metal have shadows associated with them, or contain small amounts of that metal (they may have been dislodged from their original location during flight), then they are suspected contaminants. If a particle contains only elements of reasonable cosmic abundance and is not duplicated by contaminants on non-flight collecting surfaces, then it may be considered as a candidate for an extraterrestrial origin.

Figure 4 shows photomicrographs of several particle types which illustrate these methods. Similar particles from both flight and non-flight sampling surfaces are shown. Particles (a) through (e) were found in flight modules; particles (f) through (j) in non-flight modules. Their tentative elemental composition and their approximate size is noted near each particle. Spheres and larger particles tended to be found more commonly on the tacky PVC films on the module covers. The significance of this has not yet been evaluated. Particle (a) and its non-flight counterpart (f) are very similar in sphericity, metallic

luster, and surface characteristics. Iron is the principal element of each. Particle (c) and the similar non-flight (g) are also chemically and physically similar. Particles (d) and (e) from flight slides are identical to non-flight contaminants (i) and (j). Thus, because of close similarity to known contaminants, these particles cannot be assigned an extraterrestrial origin. Particle (h) is a contaminating sphere similar in appearance to the iron spheres, but contains no iron. Sources of these contaminants have not yet been found. Particle (c) is one of the three which are extraterrestrial candidates, since no counterpart has been found on a non-flight sampling surface.

DISCUSSION

Although less than 2 per cent of the exposed sampling area has been surveyed, two observations may be formulated. First, judgment of the origin of a collected particle cannot be reliably made based on morphology alone. Close optical examination of particles found in flight modules, such as are shown in Figure 4, may easily mislead the observer into premature assignment of a cosmic origin. This is likely when the particle has a 'classical' shape often attributed to presumed extraterrestrial material, such as smooth edges or a spherical form apparently due to melting. Likewise, a good cosmic candidate may be eliminated prematurely because its physical form is similar to debris found on non-flight controls. Thus, additional chemical and mineralogical data are required before the origin of a candidate can be assigned.

Second, predictions of extraterrestrial particle collections based on the Vanguard III and Venus Flytrap experiments (Table 1) have not been substantiated by this preliminary survey. Predictions indicated that 50 or more extraterrestrial particles of sizes larger than 4μ should have been collected. Optical and electron microprobe analyses of particles found on these slides have eliminated all but a few as extraterrestrial candidates. If this present trend continues, the collection of extraterrestrial material by the Luster flight may be significantly less than expectations based on earth satellite and other sounding rocket measurements.

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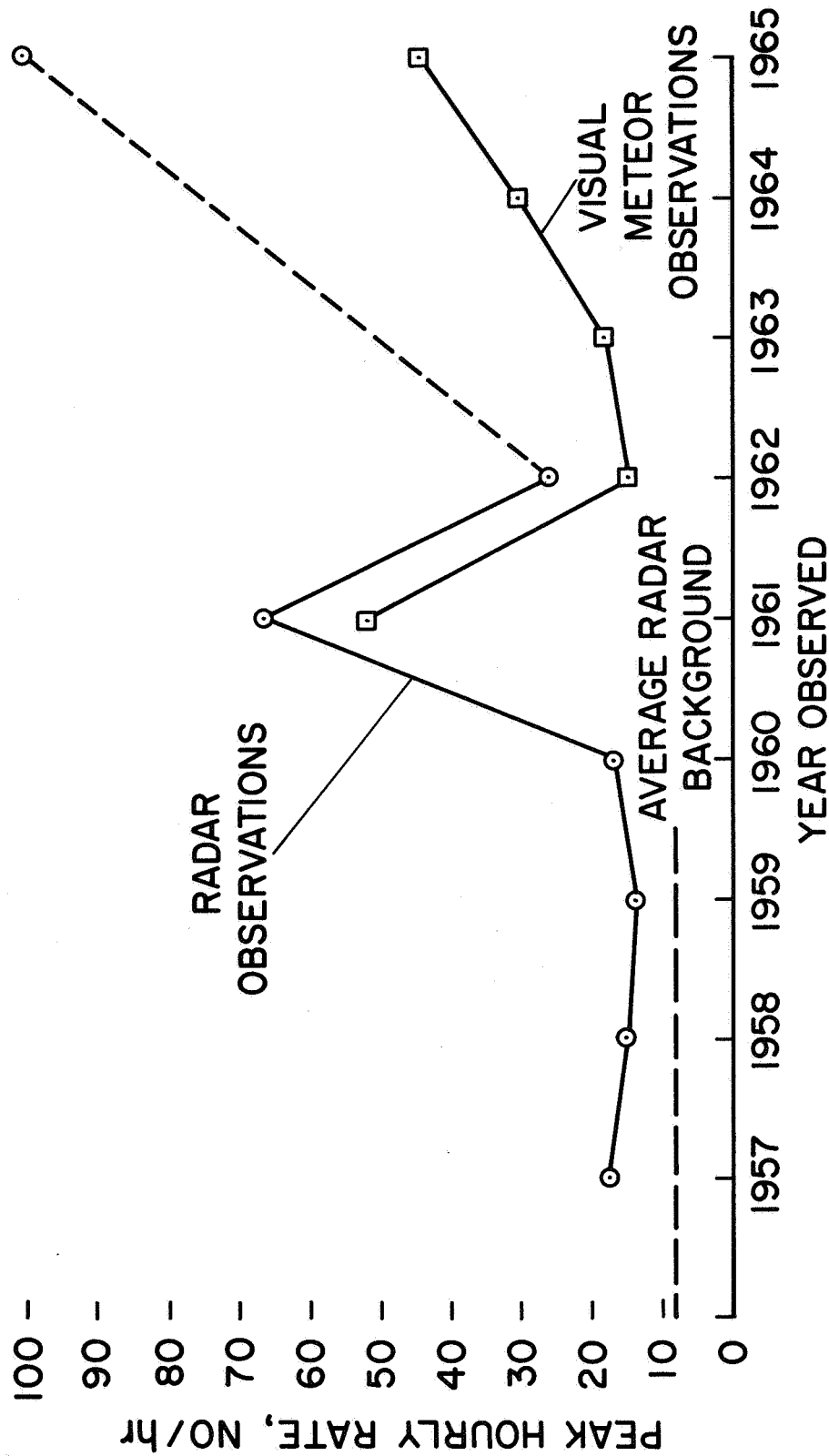
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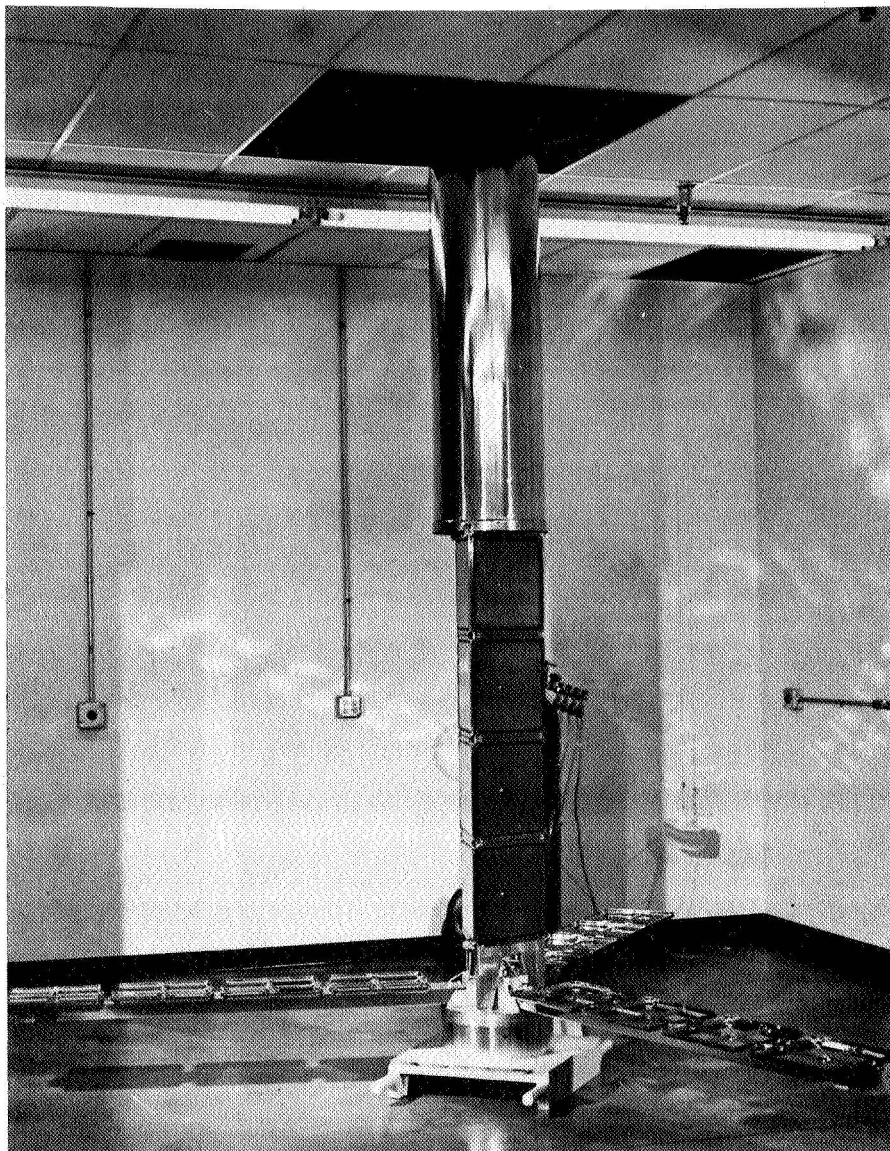
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RECENT LEONID METEOR OBSERVATIONS



AAA102-1

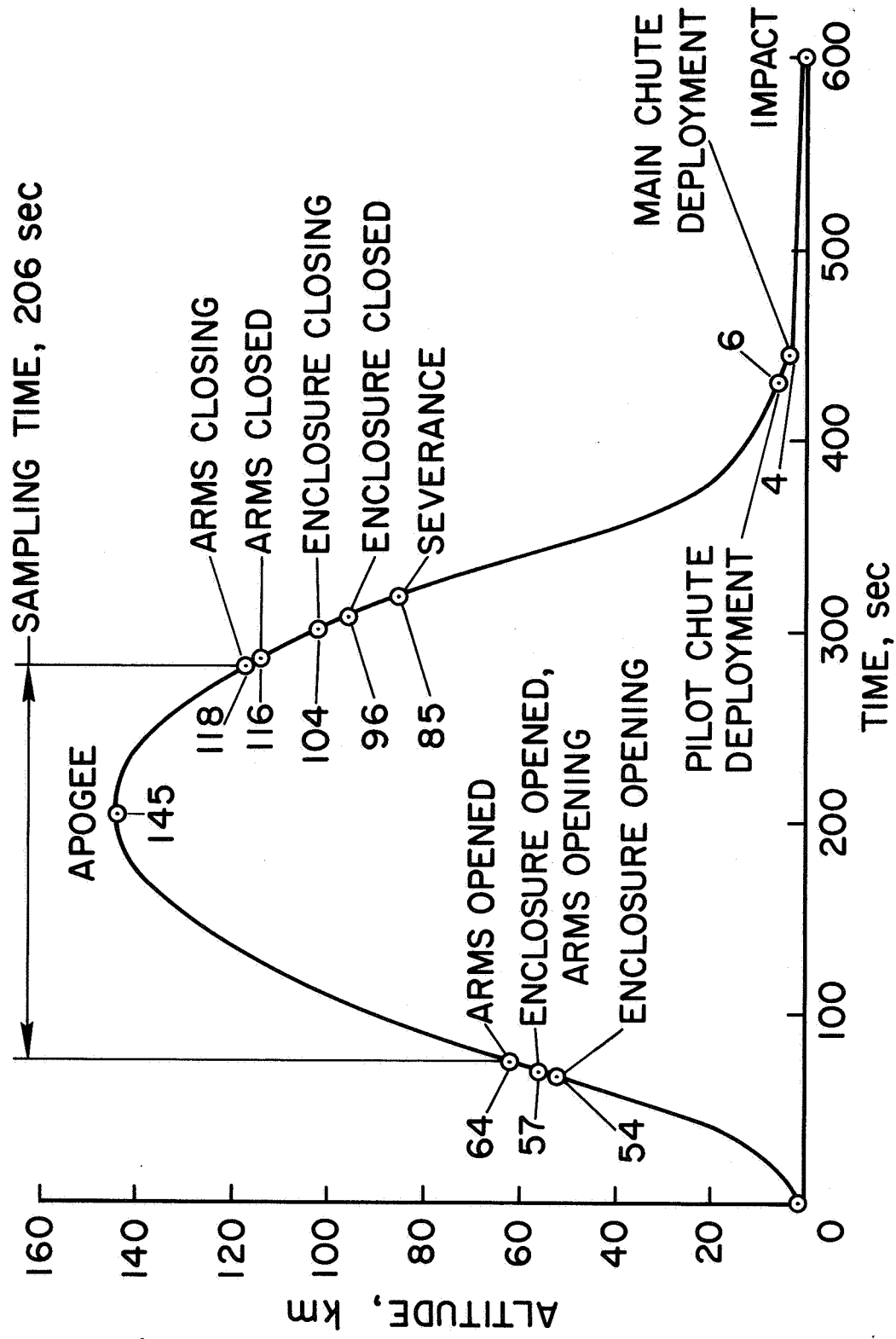
LUSTER SAMPLING INSTRUMENT FULLY OPEN



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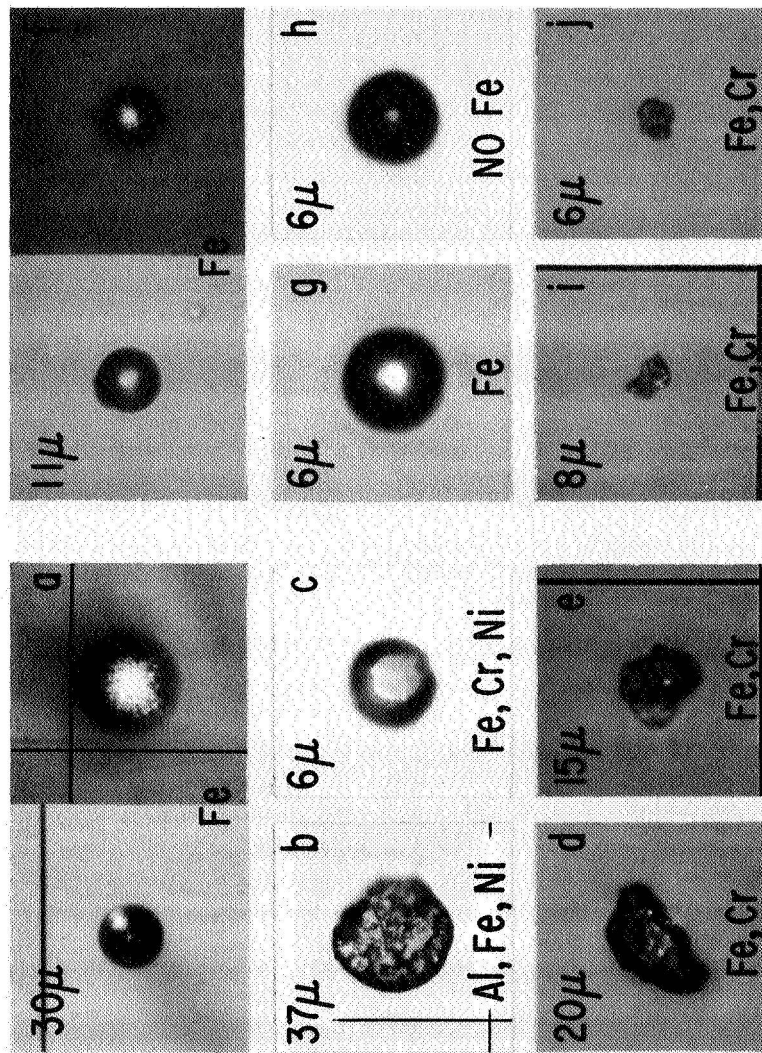
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AAA102-5

PHOTOMICROGRAPHS OF PARTICLES



AAA102-6